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CONFERENCE REPORT

45th Discussion forum on LCA—environmentally extended input–output analysis and LCA, September 15, 2011, Berne, Switzerland

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Abstract The discussion forum on life cycle assessment (LCA) on September 15, 2011, aimed at summarizing recent environmentally extended input–output analysis (EE-IOA) and the combination with LCA for the computation of environmental impact of imports. Input–output tables (IOT) represent the financial flows in a country or economic regions. Extending IOT with information on emissions and resource uses allows for the analysis of environmental impacts due to production and consumption activities in a country. This instrument is called EE-IOA. It enables the analysis of total environmental impacts of countries or economic regions. The combination with trade statistics and LCA was presented as an alternative to multiregional input–output models for determining environmental impacts of imports over the whole life cycle. The 45th LCA forum gathered several international speakers who provided a broad and qualified view on the topic. The theoretical background, results for different countries and regions, uncertainties, and possible improvement options for EE-IOA were discussed. The following main conclusions were drawn at the end of the discussion forum: EE-IOA is a useful instrument for analyzing the total environmental impacts of countries and the main drivers of environmental impacts. As a next important step, the participants would like to see an increase in user friendliness of EE-IOA combined with LCA, e.g., by harmonizing data, data formats, and classifications.

Keywords Environmental impacts due to imports · Environmentally extended input–output analysis · Total environmental impacts of countries

1 Introduction

The assessment of total environmental impacts of countries and regions has been difficult due to a lack or absence of comparable environmental data for many products. The extension of input–output tables (IOT) with statistics on emissions and resource uses (environmentally extended input–output analysis—EE-IOA—or NAMEA)[1] allows for the estimation of environmental impacts within a country. It also provides a statistical framework for comprehensive assessment of the environmental impacts of consumption and production. The compatibility, e.g., with the NACE and COICOP classification and other common classification systems, is of interest, as it allows to compare the results to other statistics and countries.

For calculating environmental aspects not only within a country or a region but also environmental impacts abroad due to imports, there are two basic approaches: (a) multiregional EE-IOA models and (b) national EE-IOA models linked with a trade module combining trade statistics and life cycle assessment (LCA).

[1] National Accounting Matrix including Environmental Accounts

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The goals of the 45th LCA discussion forum were to present the theoretical background of the approach, to provide an overview of recent and ongoing EE-IOA studies, and to discuss needs and options for future developments.

2 Environmental impacts of Swiss consumption and production

Josef Kaenzig introduced the first session by saying that, so far, EE-IOA was rarely used in Switzerland mainly because of lack of data. This gap has been filled by a recent study investigating the total environmental impacts of Swiss consumption and production (www.bafu.admin.ch/uw-1111-e). Within this project, a hybrid methodology was developed to assess the environmental impacts of imports by combining data from EE-IOA with trade statistics and LCA data. Because of Switzerland's large dependency on trade with foreign countries, the assessment of impacts abroad is essential. The study shows that environmental impacts abroad attributable to imports are higher than domestic impacts.

2.1 Needs from a policy perspective

In the first presentation, Loa Buchli from the Federal Office for the Environment (FOEN) discussed the needs and expectations for environmental information from a policy perspective. Nowadays, decision makers are confronted with an information overflow. Therefore, quality requirements are defined for environmental information. First of all, environmental information must be relevant for political and economic decisions, and it should permit the identification of the main drivers of environmental impacts. Second, it must consider all relevant impacts and the whole life cycle of products, including the environmental impacts due to imports. Thirdly, environmental information must be transparent and understandable, and it must deliver a clear overall message (Schwegler et al. 2011). As a government representative, Loa Buchli states that there is a need for aggregated environmental indicators. This need for comprehensive environmental indicators is also manifested in the Beyond GDP process (www.beyond-gdp.org). The study, commissioned by the FOEN on environmental impacts of Swiss consumption and production, is a first step towards such a recognized, comprehensive indicator.

2.2 Methodological approach and main results from the Swiss EE-IOA project

Carsten Nathani (Rütter+Partner) gave an introduction to input–output analysis and its environmental extension. He explained the methodological approach of the above-mentioned study using EE-IOA for environmental analysis. IOT show the supply and use of goods and services in the economy. Using linear algebra and IOT, it is possible to analyze how much an increase in final demand induces production through the supply chains of all industries of an economy. For an EE-IOA, the emissions and resource uses related to each industry are recorded. For households, the direct emissions and resource uses are recorded separately. The combined economic–environmental information is the data basis for the study assessing environmental impacts of Swiss consumption and production. Nathani presented the Swiss data availability with regard to IO tables, energy, and greenhouse gas emissions. EE-IOA can also be used within multiregional IO models to account for cross-boundary interactions. Another application includes structural decomposition analysis, which can explain the causes for change of emissions during a time period.

Niels Jungbluth (ESU-services Ltd.) presented the manner in which EE-IOA was combined with LCA in the study commissioned by the FOEN (Jungbluth et al. 2011). One of the main goals was to identify the most relevant areas of consumption and production for environmental impacts. The calculation of environmental impacts of imports is based on foreign trade statistics, ecoinvent data, and ESU data on demand. The life cycle impact assessment (LCIA) method "ecological scarcity 2006," which assesses more than 100 elementary flows, was used to aggregate and weight the different emissions and resource uses. This method covers a range of environmental impacts and reflects Swiss policy targets. Thus, it fits to the cultural background and framework faced by decision makers in Switzerland. One important result shown in Fig. 1 is that 60 % of environmental impacts of Swiss consumption are caused by imports. The figure also shows that a part of imported environmental impacts is re-exported again. Further analysis showed that the consumption areas nutrition, energy in housing, and mobility cause (in the framework of consumption categories used in this study) make the highest shares of environmental burdens. Although there are some uncertainties, Jungbluth stated that these results can be considered robust also if evaluated with other LCIA indicators. All inventory data are publicly available in EcoSpold format v1 and can be used in LCA software. The inventory data are also available in SimaPro.

3 Research examples illustrating the use of EE-IOA in different countries

In the second part of the discussion forum, further research examples using EE-IOA for assessing environmental impacts of Jordan and the USA were presented.

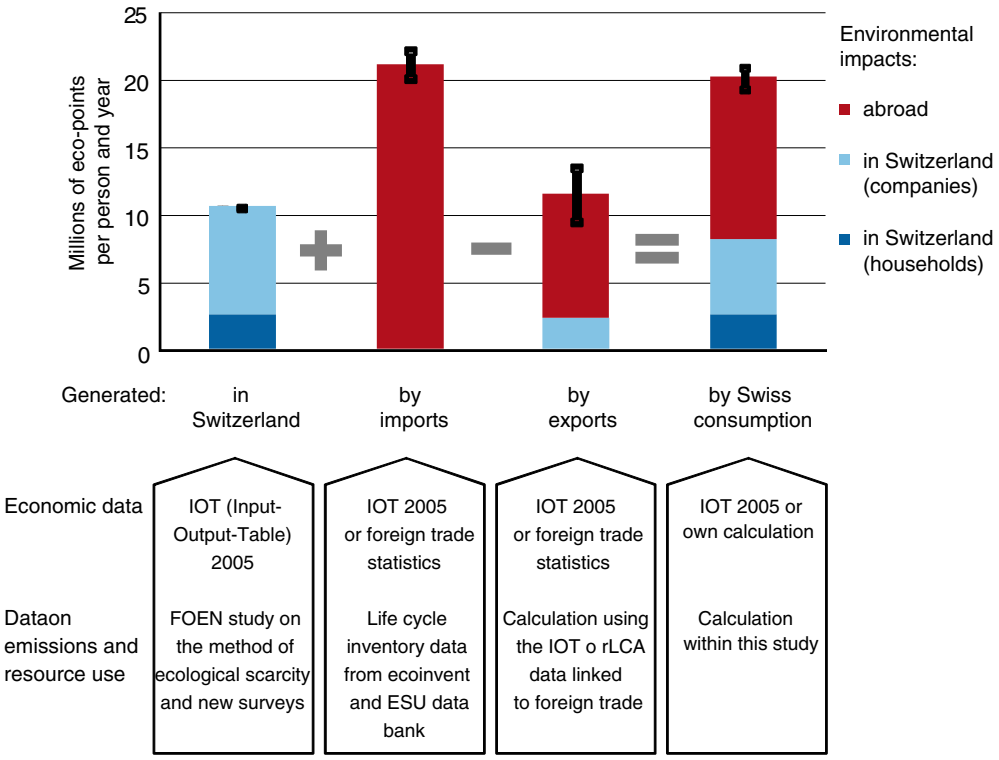

Fig. 1 Overview of the environmental impacts of Swiss consumption and production in the year 2005 (Jungbluth et al. 2011). Environmental impacts were assessed with the LCIA method "ecological scarcity." The average value of the two calculation approaches and the deviation between the two results are illustrated as the range

3.1 Adaptation of Swiss data to Jordan and to a case study on glass packages

Fredy Dinkel (Carbotech) introduced the results of an LCA on economic sectors of Jordan that is based on EE-IOA. The study provides a good basis for decision making and shows which economic sectors in Jordan have a low environmental impact per added value. In a first step, the ecological scarcity impact assessment method was adapted to Jordan, taking into account the environmental goals and the specific situation of Jordan. For example, the water scarcity in Jordan requires a higher weight (eco-factor) than in countries with abundant water sources, as for instance Switzerland or Germany. In a second step, an input–output model of the Jordan economy was built to predict the effect of changes in one industry on other industries. As a next step, the environmental burdens of the industries were divided by their added value. The input–output table was used to trace the environmental burden through the whole supply chain. The results show that environmental impacts are dominated by water use in agriculture and also in other industries. Dinkel concluded that taking into account the water scarcity is essential for ecological decisions in semiarid and arid areas such as Jordan but that it is nevertheless important to take into account other environmental impacts.

In a short presentation, Grégoire Meylan (ETH Zürich) introduced a case study on glass packages using the Swiss EE-IOA database. The goal of the study was to investigate whether there are meaningful future options for the management of discarded glass packages and dismantled flat glass for construction.

3.2 A recent example of an EE-IOA determining the environmental impacts of the USA

Sangwon Suh (University of California, Santa Barbara) acquainted the audience with the results of a computation of the total environmental impact of the US economy (EPA 2009). The study aims at quantifying the environmental impact of the US economy and analyzes its main drivers. It showed that imports generate about 28 % of the total environmental impact. He concluded that private consumption and investment are responsible for about 66 % of the total environmental impact of the US economy, with mobility, food, and housing as the main drivers. Surprisingly, the environmental impact of housing only accounts for 11 % of the total environmental impacts of the USA, which is less than in other countries. Suh presented the results with innovative flow charts which depict how environmental impacts accumulate through the supply chain. He also mentioned an EE-IOA study on environmental impacts of products in China (Yang and Suh 2011).

4 Data basis for EE-IOA and external costs

4.1 EXIOPOL, EXIOBASE, ExternE

An important improvement as far as EE-IOA is concerned can be expected with the apparition of EXIOBASE. It contains the data sets generated in the EXIOPOL project with reference year 2000. The extension of European EE-IOA with ExterneE is also of high interest for policy applications. ecoinvent is about to plan its EE-IOA management; first data integration and tests can be expected in 2012.

Arnold Tukker (TNO) presented EXIOBASE and other European EE-IOA projects. The EXIOBASE database covers 43 countries with more than 95 % of the total worldwide GDP and also includes a data set "Rest of world" combining the remaining 150 countries. For each country, 129 industries and products are discerned, along with roughly 30 emissions and 80 resources, including land and water. One country data set and an aggregated data set will be made freely available; the full multiregional environmentally extended supply and use and input–output tables with reference year 2000 will be available for a cost of around 1,500 euros per user. Investigations carried out for EXIOPOL clearly show that Europe is a net exporter of environmental pressures, which means that environmental pressures caused abroad by imports are higher than environmental pressures caused within the EU by its exports. Tukker identifies harmonization of data and classification as requiring further study.

Wolf Müller (Institute of Energy Economics and the Rational Use of Energy University of Stuttgart) focused on the application of external cost values in the EE-IOA framework of EXIOPOL (ExternE). Damages caused by energy consumption, transport, and production activities cause substantial environmental and human health damages, which are for the most part not integrated into the pricing system. For an internalization of these costs, damages must first be estimated and monetized. The ExternE methodology is widely accepted by the scientific community and is considered as the world reference in the field of estimating externalities.

4.2 Comparison of a process-based and an input–output LCA dataset

Guillaume Majeau-Bettez (Norwegian University of Science and Technology) presented a study in which a process-based LCA dataset (ecoinvent 2.1) was jointly analyzed and compared with an EEIO dataset (OpenIO 2002). These two databases were found to be complementary in the specificity and the completeness of their description of the economy (Majeau-Bettez et al. 2011). Their results point the need for a more deliberate overarching strategy in the way the LCA field gathers and accumulates knowledge; the current process-based approach does not seem to have led to the coverage of the different economic sectors proportionally to their environmental, economic, and structural importance. Concerning EE-IOA, it was found that some economic sectors suffered more than others from aggregation issues and that a bottom-up LCA approach may benefit the description of these sectors. He concluded in the presence of important research inefficiencies stemming from the actual lack of hybrid perspective in the compilation of LCA and EE-IOA databases.

4.3 EE-IOA in ecoinvent

Bo Weidema (ecoinvent Centre) presented the IO repository of ecoinvent v3.0 as a place to store make-use (IO) data in the same format as process-based LCI data, where each column in the make-use tables (including import, export, and final use) represents one activity dataset. The ecoinvent data format and the IO repository allow for the addition of physical information on resource inputs and factor-based emissions and can handle an unlimited number of monetary and physical properties for each exchange. The ecoinvent IO repository requires the integration of the formation and use of capital directly in the core make-use table and applies market activities to integrate valuation tables as well. Weidema pointed out that the repository is only a first step towards a true hybrid database, which would require further data on industry-internal activities as well as production volume and import and export data for all products in the process database. The question of who could provide and finance all these data to ecoinvent remained somehow open.

5 EE-IOA data in LCA software and LCI—conclusions from three workshops

The afternoon session was devoted to the application of EE-IOA data in different types of software. Niels Jungbluth (ESU-services Ltd.) introduced the application of the Swiss EE-IOA in SimaPro and EcoSpold v1 format. SimaPro is a comprehensive LCA software allowing the modeling of environmental impacts of products and systems from a life cycle perspective. It contains EE-IOA tables for Denmark, Switzerland, and the USA, the latter of which differentiates more than 400 industry sectors. The Swiss EE-IOA is probably the most comprehensive EE-IOA database as far as the assessed emissions and resource uses are concerned. Jungbluth explained the structure of the Swiss EE-IOA as well as how to calculate specific results with the software. With the tree function, one can visually illustrate the importance and the contribution of production sectors and consumption areas to the environmental impact. Fredy Dinkel (Carbotech AG, Basel) introduced the implementation of the Swiss EE-IOA in EMIS. EMIS is a flexible and efficient life cycle assessment software for modeling products, services, companies, or systems and calculating

the environmental impacts with a variety of different methods. The basic database included is ecoinvent. All data in the EcoSpold format v1, such as the Swiss EE-IOA, can be imported and used with EMIS. In the workshop, the advantages of a hybrid LCA approach as well as its implementation in EMIS were introduced. Bo Weidema (ecoinvent) discussed in his workshop the detailed algorithms for constructing embedded hybrid databases and for collecting and propagating price data for the ecoinvent version 3 database.

6 Discussion and needs for future developments

The plenary discussion at the end of the forum, moderated by Niels Jungbluth (ESU-services Ltd.), focused on lessons learned in workshops and during the day. It can be stated that the frontiers between LCA and EE-IOA are disappearing. The two approaches are complementary, and their integration is beneficial for both fields. Recent EE-IOA studies use LCIA to aggregate emissions and resource uses (Suh 2005).

The audience agreed that important future developments are required in the direction of harmonizing data and classifications in different statistical data sources including, e.g., the foreign trade statistics. Moreover, there is consensus that EE-IOA is a very useful instrument for analyzing the total environmental impacts of countries and the main drivers of environmental impacts.

Participants learned that the environmental impacts due to imports can be estimated by combining trade statistics and LCA quite easily for any country. The EE-IOA established for Switzerland, especially the LCA data for imports to Switzerland, can be used by other countries for the assessment of environmental impacts caused by their imports. The Joint Research Center of the European Commission has completed the prototype calculation of life cycle-based indicators for resources, products, and waste for the European Union and Germany (as exemplary member state). The results will be available online (http://lct.jrc.ec.europa.eu) in the first quarter of 2012.

Obviously, there are very sophisticated approaches and projects ongoing. An appealing and simple manner for communicating the results of such EE-IOA analyses still remains to be found. As a next important step, participants would like to see an increase in user friendliness of EE-IOA combined with LCA. All presentations of the discussion forum are available for download at http://www.lcaforum.ch/Downloads/DF45/tabid/91/Default.aspx.

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